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Volume 25, Validation of an In-Water, Tower-Shading Correction Scheme

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ABSTRACT

Large offshore structures used for the deployment of optical instruments can significantly perturb the intensity of the light field surrounding the optical measurement point, where different portions of the visible spectrum are subject to different shadowing effects. These effects degrade the quality of the acquired optical data and can reduce the accuracy of several derived quantities, such as those obtained by applying bio-optical algorithms directly to the shadow-perturbed data. As a result, optical remote sensing calibration and validation studies can be impaired if shadowing artifacts are not fully accounted for. In this work, the general in-water shadowing problem is examined for a particular case study. Backward Monte Carlo (MC) radiative transfer computations—performed in a vertically stratified, horizontally inhomogeneous, and realistic ocean–atmosphere system—are shown to accurately simulate the shadow-induced relative percent errors affecting the radiance and irradiance data profiles acquired close to an oceanographic tower. Multiparameter optical data processing has provided adequate representation of experimental uncertainties allowing consistent comparison with simulations. The more detailed simulations at the subsurface depth appear to be essentially equivalent to those obtained assuming a simplified ocean–atmosphere system, except in highly stratified waters. MC computations performed in the simplified system can be assumed, therefore, to accurately simulate the optical measurements conducted under more complex sampling conditions (i.e., within waters presenting moderate stratification at most). A previously reported correction scheme, based on the simplified MC simulations, and developed for subsurface shadow-removal processing of in-water optical data taken close to the investigated oceanographic tower, is then validated adequately under most experimental conditions. It appears feasible to generalize the present tower-specific approach to solve other optical sensor shadowing problems pertaining to differently shaped deployment platforms, and also including surrounding structures and instrument casings.

Prologue

A primary requirement for in-water optical data measurement activities is to minimize any perturbations negatively influencing the accuracy of the observations. This is particularly true when the data are used as references or *sea truth* for vicarious calibration or algorithm validation of remotely sensed ocean color data (and derived biogeochemical products). The *in situ* optical data accuracy must be defined with respect to the radiometric uncertainty budget, e.g., aimed at complying with the 5% radiometric accuracy of the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) instrument data (Hooker and McClain 2000).

Radiometric accuracy objectives can only be achieved if all the optically perturbing factors are minimized, or accounted for, so they provide an intrinsic, or corrected, radiometric uncertainty that cumulatively does not exceed the prescribed accuracy limit. Under linear perturbation hypotheses, each perturbation factor must be analyzed independently to establish its magnitude and relative importance to the total uncertainty budget. The analyses presented here only address perturbations originating from optical sensor shadowing, and emphasis is placed on the perturbation contribution brought by the instrument deployment structure, in this case an offshore oceanographic tower.

The shadowing perturbations influencing optical measurements of the in-water radiant energy field, and induced by the instrument deployment structure or by the instrument casing itself, can be quantified using three-dimensional (3-D) backward Monte Carlo (MC) simulation techniques (Gordon 1985). The measured light field intensity and directional properties are different from those existing within an unperturbed ocean–atmosphere system, because of the localized modification of optical propagation in the vicinity of the in-water instrument and the deployment platform. The local modification is a function of the spectral opacity and reflectivity, plus the finite 3-D shape, extension, and location of the intervening shadowing structures with respect to the radiation source (the sun) and the instrument detectors.

The accuracy of results generated by bio-optical algorithms, which provide biological and physical parameters of the investigated water body as a function of the *in situ* light field, is degraded by unaccounted for shadowing artifacts. These can ultimately impair the quality of ocean color calibration and validation activities. Such negative effects must be minimized wherever possible. For the instrument self-shading problem, optical data correction schemes can be based on analytical methods, as formulated by Gordon and Ding (1992) and experimentally validated by Zibordi and Ferrari (1995). When complex shadowing by large and irregular deployment structures must be addressed, a viable approach is customized look-up tables or comprehensively detailed and quasi-real time MC simulations, as proposed by Doyle and Zibordi (2002) for a specific oceanographic tower case.